Announcements

- EXAM 2 will be returned at the END of class *today*!
- NO LAB *this* Friday!
- Homework for tomorrow…

  Ch. 32: Probs. 4, 5, & 6

- Office hours…

  MW 10-11 am
  TR 9-10 am
  F 12-1 pm

- Tutorial Learning Center (TLC) hours:

  MTWR 8-6 pm
  F 8-11 am, 2-5 pm
  Su 1-5 pm

Chapter 32

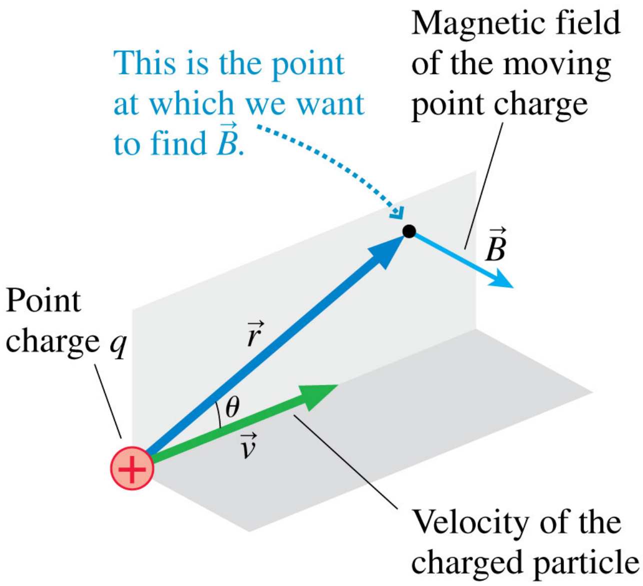
The Magnetic Field

(*The Source of Magnetic Field: Moving Charges & The Magnetic Field of a Current*)

Review…

The *magnetic field* of a charged particle q moving with velocity v is given by:

$$\boxed{B_q = \frac{\mu_0}{4\pi}\frac{qv\sin\theta}{r^2}}$$



Notice:

All charges create *E*-fields,

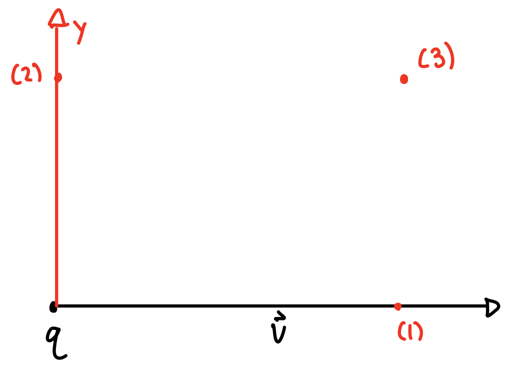
but *only* moving charges create *B*-fields.

i.e. 32.1: The *B*-field of a proton

A proton moves with velocity $\vec{v} = 1.0 \times 10^7 \hat{\imath}\ \mathrm{m/s}$. As it passes the origin, what is the *B*-field at the (*x*, *y*, *z*) positions

1. (1 mm, 0 mm, 0 mm),
2. (0 mm, 1 mm, 0 mm), and
3. (1 mm, 1 mm, 0 mm)?

$\vec{v} = (1.0\times10^7\ \mathrm{m/s})\,\hat{\imath}$



① $B_q = \dfrac{\mu_0}{4\pi}\dfrac{qv\sin\theta}{r^2}$

$\theta = 0 \therefore B_q = 0$

② $B_q = \dfrac{\mu_0}{4\pi}\dfrac{qv\sin\theta}{r^2}$

$\theta = 90$

$B_q = \dfrac{4\pi\times10^{-7}\ \mathrm{Tm/A}}{4\pi}\dfrac{(1.6\times10^{-19}\ \mathrm{C})(1.0\times10^{7}\ \mathrm{m/s})(\sin(90))}{(1.0\times10^{-3}\ \mathrm{m})^2}$

$B_q = 1.6\times10^{-13}\ \mathrm{T}\ \hat{k}$

③ $B_q = \dfrac{\mu_0}{4\pi}\dfrac{qv\sin\theta}{r^2} = \dfrac{4\pi\times10^{-7}\ \mathrm{Tm/A}}{4\pi}\dfrac{(1.6\times10^{-19}\ \mathrm{C})(1.0\times10^{7}\ \mathrm{m/s})\sin 45}{(\sqrt{2}\times10^{-3}\ \mathrm{m})^2}$

$\theta = 45°$

$r = \sqrt{2}$

$B_q = 5.8\times10^{-14}\ \mathrm{T}\ \hat{k}$

Superposition

B-fields have been found experimentally to obey the *principle of superposition*.

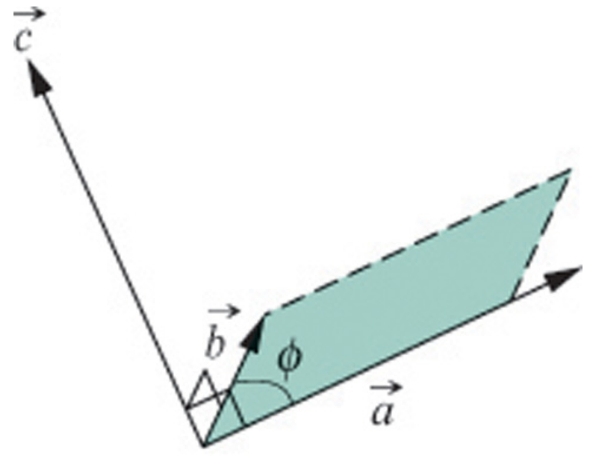
For *n* moving point charges, the *net* *B*-field is given by the vector sum…

$$\boxed{\vec{B}_{total} = \vec{B}_1 + \vec{B}_2 + \ldots + \vec{B}_n}$$

The Vector or Cross Product

The *vector or cross product* is defined as...

$$\boxed{\vec{c} = \vec{a} \times \vec{b}}$$



where the magnitude is:

$$\boxed{c = ab \sin \phi}$$

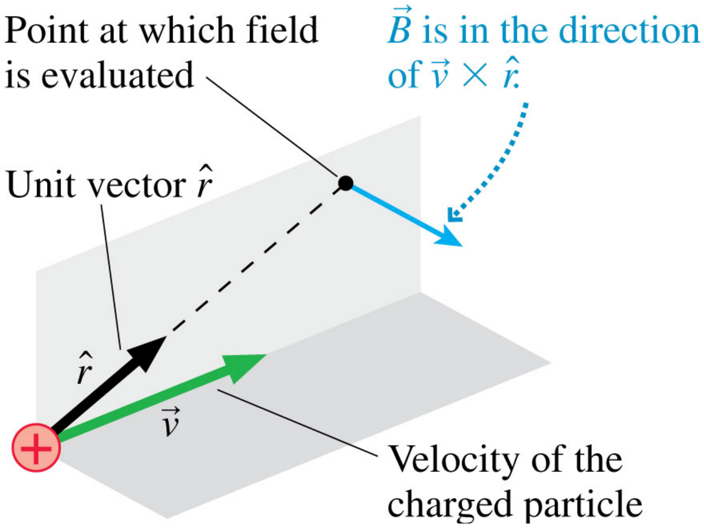
Note:

- vectors *a* & *b* form a plane, vector *c* is ⊥ to the plane
- Right hand rule gives the direction of vector *c*
- *c* = *area of the parallelogram* formed by vectors *a* & *b*.

Biot-Savart Law

The Biot-Savart law can be written in terms of the cross product

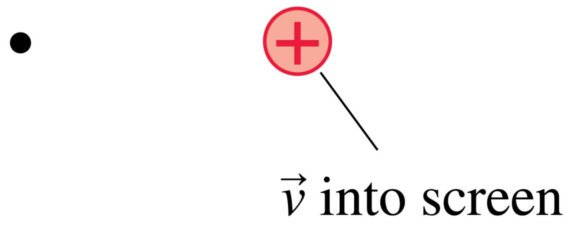
$$\vec{B}_q = \frac{\mu_0}{4\pi}\frac{q\vec{v} \times \hat{r}}{r^2}$$



where unit vector $\hat{r}$ points from charge q to the field point.

Quiz Question 1

What is the direction of the magnetic field at the position of the dot?



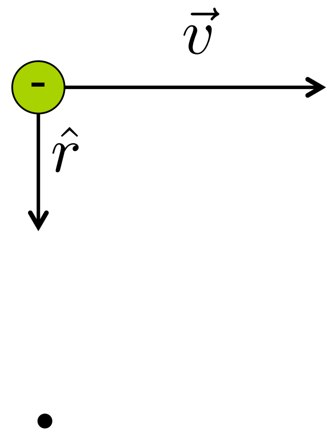
1. Into the screen.
2. Out of the screen.
3. Up.
4. Down.
5. Left.

i.e. 32.2: The *B*-field direction of a moving electron

The electron in the figure below is moving to the right.

What is the direction of the electron's *B*-field at the position indicated with a dot?

Points out of Screen



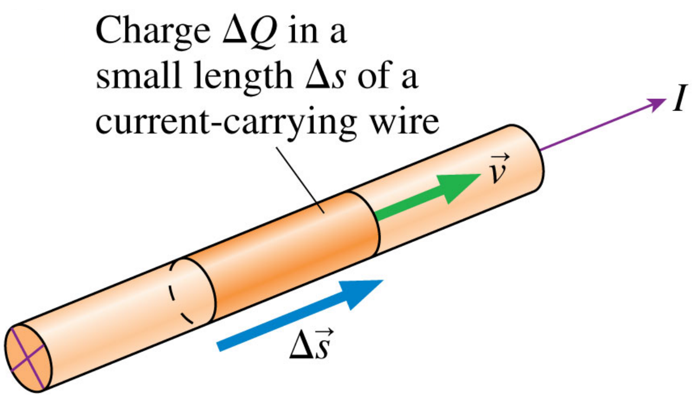
32.4:
The Magnetic Field of a Current

The B-field of a very short segment of current is..

$$B_q = \frac{\mu_0}{4\pi} \frac{\Delta Q \vec{v} \times \hat{r}}{r^2}$$

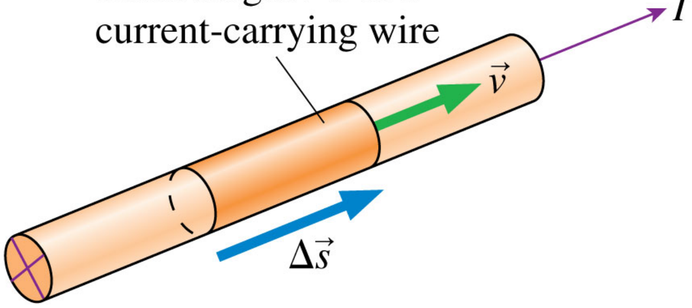
$$\Delta Q \vec{v} = \Delta Q \frac{\Delta \vec{s}}{\Delta t} = \frac{\Delta Q}{\Delta t} \Delta \vec{s} = I \Delta \vec{s}$$

$$B_q = \frac{\mu_0}{4\pi} \frac{I \Delta \vec{s} \times \hat{r}}{r^2}$$



32.4:
The Magnetic Field of a Current

The *B*-field of a very short segment of current is..

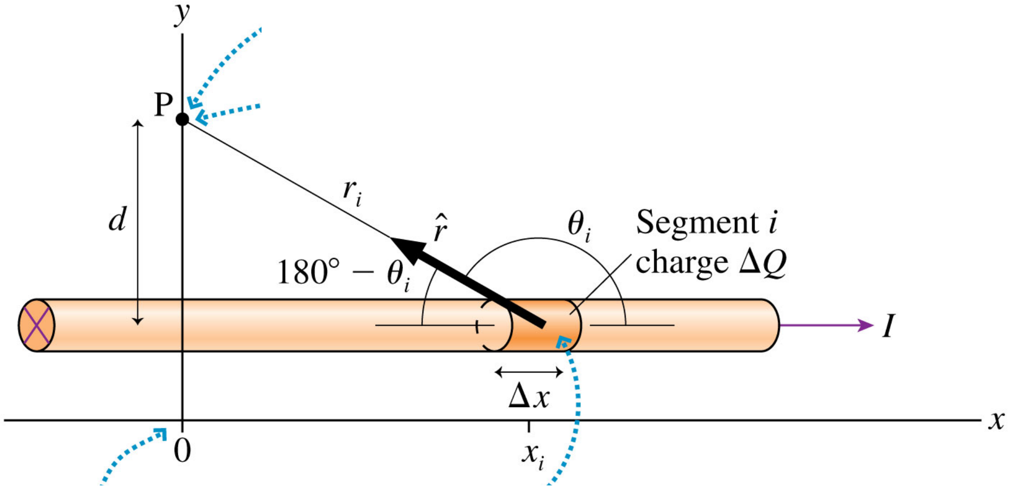


$$\vec{B}_{I\ seg} = \frac{\mu_0}{4\pi}\frac{I\Delta\vec{s}\times\hat{r}}{r^2}$$

i.e. 32.3:
The *B*-field of a long, straight wire

A long, straight wire carries current I in the positive x-direction.

Find the B-field of a point that is distance d from the wire.



i.e. 32.3: The *B*-field of a long, straight wire

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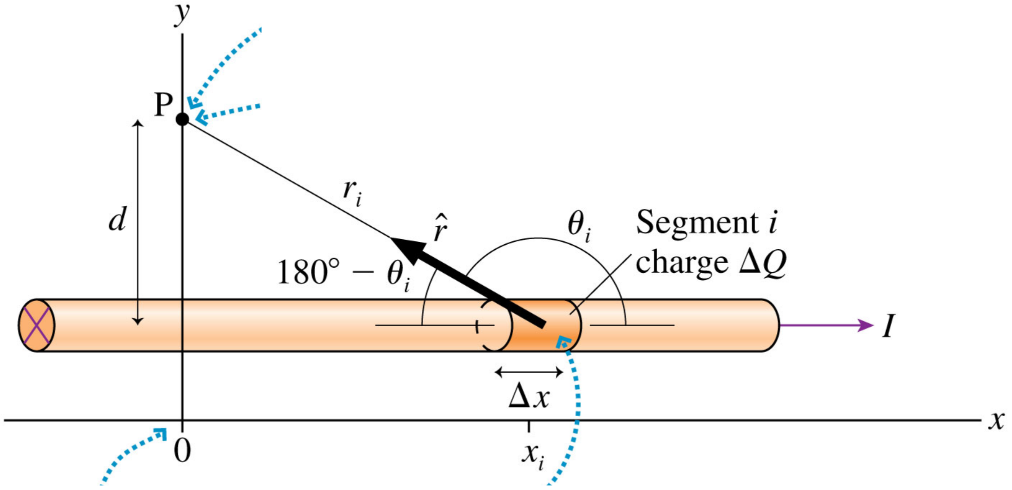

$$\boxed{B_{wire} = \frac{\mu_0 I}{2\pi d}}$$